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A METHOD FOR MAKING AN INJECTION MOLDABLE FEEDSTOCK WHICH CAN PROVIDE ARTICLES WITH IMPROVED PHYSICAL PROPERTIES

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A METHOD FOR MAKING AN INJECTION MOLDABLE FEEDSTOCK WHICH CAN PROVIDE ARTICLES WITH IMPROVED PHYSICAL PROPERTIES

FIELD OF THE INVENTION

This invention relates to a method for making feedstock materials that can be injection molded to produce articles with improved physical properties, and a feedstock made thereby.

BACKGROUND OF THE INVENTION

Polymer composite enclosure bodies provide light and durable protection for various equipment, particularly, for electronic gadgets. Some polymer composite enclosure bodies protect the highly complex inner workings of devices such as cameras, radios, cassette players, DVD players, CD players, TVs, and other portable devices of the modern age. Unfortunately, a belief has arisen in the consumer community that devices that have polymer or plastic enclosure bodies are inherently less sophisticated, less expensive, and less aesthetically appealing than metal enclosure bodies. Some attempts to address the aesthetic appeal have included using and/or applying various colors to polymer composites. Users frequently judge injection molded polymeric articles on the basis of their weight and also their tactile properties. Typically, the polymeric materials do not have enough weight or mass and also do not have good tactile properties to be aesthetically pleasing.

SUMMARY OF THE INVENTION

It is an object of this present invention to provide a material which is particularly suitable for injection molding so that the injection molded article will be aesthetically pleasing in terms of weight and tactile feel. This object is achieved by providing a method of making a feedstock for injection molding, including the steps of: mixing at a temperature of at least 100° C polymeric materials having a thermal conductivity in the range of 0.001 to 0.01 cal/cm-sec-° C wherein the polymeric materials are selected from the group consisting of polyethylene, polystyrene, polyester, and polycarbonate or combinations thereof,

and one or more materials selected from the group consisting of ceramics, ceramic composites, metals and metal alloys in a blended relationship to form a viscous phase mixture, the materials in the viscous phase mixture being selected so that when in a solid phase it has a density greater than 4 grams/cc and a thermal conductivity greater than 0.101 cal/cm-sec-$^{\circ}$ C and; cooling the blended viscous phase mixture to form the feedstock.

The advantages of the present invention include:

Developing a family of organic/inorganic composite feedstock which can be successfully utilized in manufacturing injection molded articles with superior mechanical, physical, and tactile properties.

Combining a very cost-effective feedstock which can be readily injection molded to form articles with enhanced mechanical, physical, and tactile properties.

Recognizing that articles made with a feedstock in accordance with the present invention can have high mechanical strength, can have small cross-sectional dimensions and can be made with reduced material cost and processing time.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic block diagram showing the various steps in making a mixture which can be formed into a solid article, pelletized, and injection molded to form an article.

DETAILED DESCRIPTION OF THE INVENTION

This invention generally relates to a method of making injection molding feedstock by mixing complex, net-shaped plastic or polymer composites with inorganic materials, for example, ceramics and metals, and subsequently compounding the mixture prior to an injection molding process. More particularly, this invention relates to a method of injection molding polymers compounded with ceramics and or metal or alloys. The compounding method involves mixing inorganic particulates such as ceramic or metal or alloy powders with polymers or plastics, such as polystyrene (commercially available in the

name of Zylar®) in appropriate proportions at an elevated temperature. The mixing is done at a relatively high temperature ranging between 100° and 150° Centigrade under a high shear condition using a twin screw mixer. Mixing time generally varies between 2 and 12 hours so that a uniform mixture is obtained. The mixture is then cooled to room temperature and pelletized to provide feedstock for the subsequent injection molding process, the details of which are described below.

Referring to Fig. 1, a block diagram of an example embodiment of a compounding and injection molding process where polymeric and ceramic composite powders are initially mixed in proper proportions in step **105**. All the ingredients (as described in working examples) are initially heated within a temperature range of 100 to 150° C (preferably, between 110 to 150° C, and depending on the specific ingredients that are mixed) in step **110** and blended in a twin screw mixer in step **115** until all the organic or polymeric materials are dissolved and intimately mixed with the inorganic materials such as ceramics, ceramic composites, metals, and metal alloys. Next step is to analyze the blend in step **120** either by standard chemical analysis methods or by X-ray diffraction, or by employing X-ray florescence analysis in order to establish the blending process. Based on the analysis, for example, determining the likely final strength or color component, the ingredients are adjusted to fine tune the process in step **125**. In the next step **130** of the process the temperature of the mixer is increased to a range of 100° to 150°, preferably to 130° C, and extended blended for at least 2 to 12 hours in step **135**, preferably 4 hours and the compounded mixture is cooled to room temperature in step **140**. The cooled compounded mix is then either shredded to small pieces or pelletized in step **145** to provide feedstock for the subsequent injection molding process in step **150**. The injection molding was carried out in a machine manufactured by Boy, Model # 22M. The injection-molded parts and/or enclosure bodies in step **155** were inspected carefully so that the enclosure bodies did not warp due to flaws in the injection molding process parameter selection.

Some inherent physical properties (like thermal conductivity and density), of all commercially available plastics (polymers) are inferior to those of

metals or ceramics. As a result, the human perception and experience of plastic is neither very complimentary nor very pleasant. Plastic is usually viewed as a material that is relatively inexpensive and not durable. On the other hand, there are commercially available plastic-based composites which are designed for heavy-duty applications and are generally more expensive than either engineering plastic or engineering metals. Therefore, a need exists for developing special composite materials which are not as expensive as metals, ceramics or commercially available plastic-based composites. The injection molded composites of the present invention can include plastics, ceramics, and metals. These injection molded composites overcome all the negative attributes of plastics, and compliment the family of commercially available plastic-based composites. The composites of the present invention do provide enhanced physical attributes such as better tactile properties than plastics, and do have an apparent feel of durability and value.

Experiments were conducted to develop injection moldable composite feedstock having enhanced physical attributes as mentioned above, comprising a mixture of polymers, metals, metallic alloys or ceramics. Engineering plastics, generally used for manufacturing component housing, such as polyethylene, polystyrene, polyester, and polycarbonate, were selected as polymeric components for the composite mix. Metals and alloys were selected and classified into various groups based on their physical appearance and mechanical and physical properties. One such group comprised Al, Ti, Mg, Al-Ti-V alloys, and/or mixtures thereof. Another group consisted of Ni, Cr, stainless steel, and/or mixtures thereof. Similarly, ceramics were selected based on the same criteria as metals and alloys. They too were classified into several groups. One such group comprised thermally and electrically insulating oxides, such as alumina, zirconia, magnesia, silica, and/or mixtures thereof. Another group comprised thermally conductive carbides, such as SiC, TiC, B_4C, WC, and/or mixtures thereof. Oxide ceramics having a wide spectrum of colors were selected for mixing with polymers and/or metals to form a class of composites for our application. Oxide ceramics which exhibit a wide variety of colors are generally those which are the oxides of transition elements like V, Cr, Mn, Fe, Co, Ni., and

also the oxides of rare earth elements like La, Ce, Pr, Nd and Gd, and/or mixtures thereof. Whereas, nitride ceramics were selected for their excellent physical properties and also variety of colors, e.g., TiN, silicon nitride, BN, zirconium nitride, and/or mixtures thereof.

The injection molded composite parts comprising polymer-ceramic, polymer-metal, polymer-metal alloy, and polymer-metal-ceramic were evaluated for various physical and mechanical properties. Most of the injection molded composite parts had the physical appearance and feel of plastics. Physical and tactile properties of the composites varied widely depending on the volume fraction of each constituent and their relative physical and mechanical properties. But, surprisingly few injection molded composites had physical appeal and tactility which differentiated them from commercially available plastics and polymer-based composites. Physical and mechanical properties of those composites were measured and their physical appeal was evaluated for our application.

There are many measurable physical properties, such as thermal conductivity, specific heat, density, surface texture, and coefficient of friction, which contribute to the human perception of good physical appeal of a given material. Unlike those measurable physical properties, there are some physical characteristics, which cannot be measured quantitatively but are directly related to human perception for a good quality material. Those physical characteristics are tactility, surface texture, pleasing color, etc., which have some relationship with density and thermal conductivity of materials. Therefore, we chose two fundamental properties of materials, e.g., thermal conductivity and density and those properties were used to rank the physical appeal of the composite materials of this invention. Various colors of the composite materials of this invention also were a factor in the selection process. Materials possessing low thermal conductivity and low density generally were shown to have also poor physical appeal. As a result, those poorly appealing materials were ranked low, L. Most of the commercially available plastics fall in this category. Similarly, materials possessing moderate to high density and low to moderate thermal conductivity or vice versa were ranked medium, M. Some metals and ceramics fall in this

category. Furthermore, materials possessing both high density and high thermal conductivity, were ranked high, H. Many precious metals fall in this category.

The two fundamental properties of materials, i.e., density and thermal conductivity, which were used to formulate a "standard" for the composite materials as designated by L, M, or H, were applied to the injection molded composites in this invention. Those composites, which ranked L were not accepted for our application. Conversely, those composites which ranked M and H were accepted for our application. The acceptance criteria for composite materials of this invention were derived from the known value of standard materials, which are perceived to have high tactile properties and high physical appeal. For example, polymeric materials having a thermal conductivity in the range of 0.001 to 0.01 cal/cm-sec-$^{\circ}$ C, and that are selected from the group consisting of polyethylene, polystyrene, polyester, and polycarbonate or combinations thereof, and one or more materials including, ceramics, ceramic composites, metals and metal alloys in a blended relationship to form a viscous phase mixture, the materials in the viscous phase mixture being selected so that when in a solid phase it has a density greater than 4 grams/cc and a thermal conductivity greater than 0.101 cal/cm-sec-$^{\circ}$ C were found acceptable.

The following Table 1 shows the ranking of the materials to low (L), medium (M), and high (H) which is derived from the numerical values of density and thermal conductivity.

The injection molded composites which ranked M and H were acceptable for our application provided they met the criteria of mechanical properties. Therefore, all the injection molded composites, which ranked M and H, were evaluated for their mechanical properties in terms of tensile strength, modulus of rupture and impact resistance. The injection molded article should preferably have a modulus of elasticity greater than 32,000 psi and a fracture stress greater than 3,500 psi.

TABLE 1 - Density, gram/cc

L	M	H
1 - 3.9	4 - 6.9	above 7

TABLE 2 - Thermal Conductivity, cal/cm-sec-°C

L	M	H
0.001 - 0.100	0.101 - 0.150	above 0.150

TABLE 3 – Physical Appeal (Arbitrary Unit)

	L	M	H
Density	<3.9	<3.9	>3.9
Thermal Conductivity	<0.1	>0.1	>0.15

TABLE 4 – Physical Properties of Some Standard Materials

Material	Class	Density (g/cc)	Rank (L,M,H)	Thermal Conductivity (cal/cm-sec-°C)	Rank (L,M,H)	Physical Appeal Ranking (L,M,H)
Polystyrene (Zylar®)	Polymer	1.05	L	0.003	L	L
Gold	Metal	19.32	H	0.746	H	H
Silver	Metal	10.50	H	1.013	H	H
Copper	Metal	8.96	H	0.943	H	H
Aluminum	Metal	2.90	L	0.562	H	M
316 stainless steel	Alloy	8.0	H	0.039	L	M
Alumina	Ceramic	3.9	L	0.06	L	L
Zirconia	Ceramic	6.08	M	0.009	L	M
SiC	Ceramic	3.2	L	0.15	M	M
TiC	Ceramic	7.7	H	0.03	L	M
Si3N4	Ceramic	3.2	L	0.05	L	L

TABLE 5 - Working Examples

Example #	Composite Composition (% by weight)	Density (g/cc)	Thermal Conductivity (cal/cm-sec-oC)	Physical Appeal Ranking (L,M,H)
Example 1	*Zylar® 10% + zirconia 70% + gold 20%	8.22	0.155	H
Example 2	Zylar ®10% + TiC 60% + Al 30%	5.59	0.1869	H
Example 3	Zylar® 30% + alumina 50% + 316 ss 20%	3.865	0.0387	L
Example 4	Zylar® 30% + SiC 60% + Ag 10%	3.285	0.1922	M

*Zylar® is commercially available polystyrene

The working examples given in Table 5 are some typical examples of the compositions we experimented with. Injection molded composites in Example 1 and 2 had a very high physical appeal, which is validated by our arbitrary ranking system, H. These composites did not appear or even felt like any known plastics, but rather were perceived to have added an extra sense of value and durability. Although the physical appeal of the composite in Example 4 was ranked M and acceptable for our application, these do materials have some remote resemblance to plastics. The composite material illustrated in Example 3 was not accepted for our application because the physical appeal of this material was more akin to plastics or commercially available composites.

The aforementioned selection standard was applied to the injection molded composites in this invention. The injection molded composites comprising:

a) 10 to 30% by weight Zylar®,

b) 50 to 70% by weight oxide ceramics, comprising alumina, zirconia, magnesia, silica, and/or mixtures thereof,

c) 50 to 70% by weight oxides of transition elements like V, Cr, Mn, Fe, Co, Ni., and also the oxides of rare earth elements like La, Ce, Pr, Nd and Gd, and/or mixtures thereof,

d) 20 to 70% by weight carbide ceramics, comprising SiC, TiC, B_4C, WC, and/or mixtures thereof,

e) 20 to 70% by weight nitride ceramics, comprising TiN, silicon nitride, BN, zirconium nitride, and/or mixtures thereof,

f) 0 to 20% by weight Ti, Al, Mg, and/or mixtures thereof,

g) 0 to 15% by weight Ni, Cr, stainless steel, and/or mixtures thereof,

h) 0 to 15% by weight V, Cr, Mn, Fe, Co, and/or mixtures thereof,

i) 0 to 15% by weight La, Ce, Pr, Nd and Gd, and/or mixtures thereof, have superior physical and mechanical properties compared to plastics.

The shredded feedstock from Examples 1, 2, 3, 4 and 5 were fed in to a BOY Model 22M injection molding machine to form parts having various geometric configurations. The following are some typical injection molding parameters:

clamp pressure:	150 bar
injection pressure	40 bar
molding temperature	200 to 230° C

Enhancement in mechanical properties due to composite formation with organic (polystyrene) and inorganic (ceramic) materials:

Sample #	Material	Compound	Per-centage	Modulus of Elasticity (PSI)	Fracture Stress (PSI)	Impact Energy (ft. lb.)
A382	Zylar	none		329674	3503	21.94
A436	Zylar	Calcined Alumina	5%	320769	3601	22.11
A436	Zylar	Calcined Alumina	50%	644743	4965	22.055
A436	Zylar	Calcined Alumina	75%	164353	6973	22.155
A453	Zylar	Zirconia	5%	332887	3816	
A435-1	Zylar	Zirconia	10%	335930	3835	22.00
A435-2	Zylar	Zirconia	50%	459977	4010	
A435	Zylar	Zirconia	75%	753365	4934	

Enhancement Of Liking As Determined By Interviewing People:

Question	A	B	C	D	E	F	G	H
Which part looked like the more expensive material ?			15%			80%		5%
Which part feels like the more expensive material ?			5%	10%		75%	10%	
Which part considering appearance and weight would make you purchase a camera made from the material used ?	5%	15%	5%	10%		50%		15%
Which part would make you purchase a camera from the appearance only ?	5%	35%	10%	10%		25%	5%	10%
Which part would make you buy a camera buy the way it feels only ?	5%		5%			85%		5%

A- Zylar with 10% buy weight Zircona Oxide
B- A mixture of colors that give a marble appearance
C- Zylar coated with Aluminum flakes from spray paint
D- Zylar with Gold Bronze Flakes added
E- Zylar that was laid out in a pan and sprayed with gold spray paint
F- Zylar that was compounded with 65% by weight of calcined alumina
G- Zylar with bumper chrome spray paint
H- no opinion

PARTS LIST

105	initial mixing step
110	initial heating step
115	blending of mixture
120	analyze blended mixture
125	adjust mixture
130	secondary heating step
135	extended blending of mixture
140	cooling step
145	pellet forming step
150	injection molding of pellets
155	forming enclosure bodies